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Minor rural road networks: values, challenges, and opportunities for biodiversity conservation

Peter G. Spooner[1]

1 *Institute for Land, Water and Society, Charles Sturt University, Albury NSW 2640, Australia*

Corresponding author: *Peter G. Spooner* (pspooner@csu.edu.au)

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Abstract

Roads corridors are a conspicuous part of most landscapes, which are gaining greater recognition for their role in nature conservation. However roads cause wildlife mortality, alter water and nutrient flows, change local microclimatic conditions, act as vectors for weeds and pest animals, and have other far-reaching effects. Not surprisingly, there is much attention from both road and conservation managers to lessen these impacts, with an emphasis on developing solutions to mitigate the barrier effects of major roads to wildlife movements. However in many anthropogenic landscapes, road corridors can also provide key habitat and connectivity for local biodiversity. In particular, where traffic volumes are low, minor roads often provide critical habitat and refuge for many native species. Knowledge of the ecology and biodiversity conservation values of minor rural road verges has been underpinned by studies in various contexts, such as sunken roads, field margins and hedgerow networks in Europe, to stock routes in Spain and Australia. Despite their different histories and management constructs, important commonalties have been highlighted in terms of their biodiversity values, and the factors which influence these values. As such, minor rural road networks can be vital in providing connected, functioning ecosystems within rural landscapes. The importance of vegetated minor rural road networks will only become more pressing with future climate change. In Australia, road management authorities are tasked with the dual roles of maintaining road transport needs (i.e. priorities for road maintenance and safety concerns), whilst maintaining the environmental values of roads. This paper reviews the biodiversity values of minor rural roads, discusses the challenges and constraints in managing these values, and describes the case of identifying historic roads as an example of enhancing conservation management of these important habitats in rural landscapes.

Keywords

Linear corridors, road ecology, roadside vegetation, stock route

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Introduction

Intensive agriculture has caused irreversible damage to many ecosystems and constitutes a major threat to biodiversity (Sachs et al. 2010). Agricultural-related practices such as land clearing, intensification, inappropriate water-use, and over application of fertilizers have accelerated biodiversity losses worldwide (Conacher and Conacher 1995, Pretty et al. 2010). Such human modification and destruction of habitat has transformed once continuous ecosystems into landscapes dominated primarily by mixed pastures and food crops (Lindenmayer and Fischer 2006). Due to changing economies and policies, agricultural (and other human modified) landscapes often experience frequent and extensive land-use changes, the history of which continues to shape present-day landscape patterns and processes (Foster et al. 2003, Watson et al. 2014). This process results in extensive fragmentation of remaining habitat, creating isolated remnant habitats of varying size and quality (Saunders et al. 1991). Despite these changes, road transport corridors can provide vital refuge for species and remnant ecological communities (Bennett 1991, Votsi et al. 2012).

Roads and other infrastructure corridors are a conspicuous part of most agricultural and other human modified landscapes, and have significant impacts on adjacent ecosystems (Lugo and Gucinski 2000). For example in Europe, the impact of expanding road networks and associated urbanisation was recently described as effectively 'cutting to pieces' local ecosystems (BISE 2014), resulting in significant biodiversity losses – even in protected areas (EEA 2014). The rapid expansion of road networks into natural areas or farming systems in recent decades has become a global phenomena impacting upon production (Forman et al. 2003, Hoffman et al. 2014). The need to produce more food from dwindling farmlands means further intensification, and further pressure to upgrade existing rural road networks (Pauwels and Gulink 2000). As a result, potential positive effects of roads for biodiversity conservation may be eroding, as human populations expand.

Road networks typically consist of a system of interconnected road corridors, which are usually classified into the following categories: highways (paved), main roads (paved), minor secondary roads (heavily populated areas – usually paved; unpopulated rural areas – usually unpaved, gravel roads) and tracks (natural earth surface) (Spooner et al. 2004, FHWA 2013). Road surface conditions usually reflect the frequency of use by vehicles, where motorways and other major highways can account for up to 65% of vehicle movements (UKDT 2013), yet constitute a small proportion of the entire network length (Hambrey Consulting 2013). Although a small component of road networks, highways and other major roads constitute a significant barrier to animal movements, are a major cause of wildlife mortality, and can cause significant vehicle damage. As a result, most attention by environmental researchers has focussed on the negative effects of highways in relation to wildlife (e.g. Trombulak and Frissell 2000, Forman et al. 2003, Underhill and Angold 2000), and methods to mitigate the conflict between transportation and nature (Morelle et al. 2013).

Given the depauperate state of human modified landscapes, there is growing attention on the role of minor roads to conserve biodiversity. Although minor roads

are primarily used for transportation, their biodiversity conservation values have long been recognised, and underpinned by various studies and contexts: from roadside environments in Australia and elsewhere, to field margins and hedgerows in much of Europe (e.g. Perring 1967, Foreman and Baudry 1984, Riffell and Gutzwiller 1996, Spellerberg 1998, Dover et al. 2000, Lugo and Gucinski 2000, Freemark et al. 2002, De Blois et al. 2002, Marshall and Moonen 2002, Spooner and Lunt 2004, Deckers et al. 2005, Huijser and Clevenger 2006, Noordijk 2009). Minor rural roads are the most common type of road, and frequently harbour the last vestiges of quality habitat (Bennett 1991). As a result, minor roads often provide important refuge and connectivity for many threatened species (e.g. Bennett 1991, Dennis 1992, Dover et al. 2000, van der Ree 2002, Spooner and Lunt 2004), particularly in low populated rural areas. However in more heavily populated areas such as Central Europe and the eastern states of USA, environmental change has been such that few elements of previous ecosystems remain.

Minor roads are usually narrow, possess a high edge: interior ratio, and are maintained by humans (Forman 1991). Therefore they are subject to a suite of influences from the surrounding environment (Forman and Alexander 1998, Joly et al. 2011) making them highly susceptible to invasion by exotic species (De Blois et al. 2002, Jauni and Hyvönen 2010, Schmitz et al. 2007, Kalwij et al. 2008, Šerá 2010). Various studies have shown that roadsides are often colonised by opportunistic pioneers that enjoy increased nitrogen (Cilliers and Bredenkamp 2000, Zwaenepoel et al. 2006) and available light conditions (Lavoie et al. 2007). Owing to their linear configuration and connectivity to other habitats, minor roads are often been blamed for acting as conduits for plant invasions (e.g. Gelbard and Belnap 2003, Dark 2004, Pauchard and Alaback 2004, Kalwij et al. 2008, Barbosa et al. 2010, Brisson et al. 2010). Many species can disperse over long distances throughout human modified landscapes because roads create continuous habitat over many kilometres (Christen and Matlack 2006). Minor roads can also facilitate plant invasions into adjoining ecosystems, particularly when the road corridor intersects areas of intact habitat (Tyser and Worley 1992, Flory and Clay 2006, Vilà and Ibáñez 2011).

The extent to which minor roads provide biodiversity conservation benefits for species, as opposed to promoting alien flora and fauna, is largely dependent past land-use history and ongoing disturbances experienced in roadsides (Spooner et al. 2004, Hansen and Clevenger 2005, Barbosa et al. 2010). The maintenance of minor roads can alter soils, light levels, dust, patterns of water runoff and sedimentation, and introduce nutrients and other pollutants to adjacent roadside environments (Gelbard and Belnap 2003, Trombulak and Frissell 2000). Unlike natural disturbances such as fire, disturbances in roadsides are often repeated more frequently and with far greater intensity than most natural events (Frenkel 1970, Hobbs 1987, Spooner et al. 2004). As a result, roadsides are highly susceptible to invasion by exotic plant species (Tyser and Worley 1992, Vitalos and Karrer 2009, Jauni and Hyvönen 2010). However some studies have shown that disturbances associated with road maintenance can play an important role in the recruitment of native plants into roadsides (e.g. Spooner et al. 2004, Bognounou et al. 2009). For example, disturbance events can assist threatened

species with limited dispersal mechanisms (Eriksson and Eriksson 2000) and assist grassland flora to disperse into roadsides (Tikka et al. 2001).

The growing body of literature (above) suggests that conserving biodiversity in minor rural road corridors is indeed problematic; where competing human-use values, inherent complexity of the roadside ecosystems, and limited resources are contending issues for management to deal with. However greater recognition of the need to develop road networks in a sustainable manner provides the impetus and incentive to identify new opportunities for restoration and biodiversity conservation measures to be undertaken (Dolan et al. 2006). As minor rural roads constitute a significant proportion of remnant native vegetation in many agricultural areas, conservation of roadside habitats can complement efforts to achieve more sustainable agriculture, and build greater ecosystem resilience in preparation for climate change. The aim of this paper is to discuss the management of minor roads from an environmental viewpoint, by describing the competing values, management considerations and new opportunities to explore in conserving biodiversity in rural landscapes.

Australian context – history of minor roads

Roadside environments are a ubiquitous component of the Australian landscape. Fringing a vast network of minor rural roads, remnants of native vegetation still exist alongside many Australian roads, and provide the only remaining evidence of once extensive tracts of forests, woodlands and grassland ecosystems. In conjunction with stock routes (see below), roadsides often constitute a significant proportion of native vegetation remaining in agricultural or urbanized areas, and provide important refuge for threatened or endangered species and ecosystems (Figure 1). As such, this infrastructure is one of the most extensive networks of its kind in the world. Australia is fortunate to possess this 'green' network, but how did they get there?

The history of road development in rural areas of Australia has been described by Spooner (2005) and others. Briefly, the narrow area of land which contains the road and surrounding environment is dedicated as a road 'reserve' – an area of public land set aside for transportation needs during European colonisation of Australia in the early 19th century. As landscapes were surveyed and subdivided for settlement, an extensive network of road reserves was also surveyed so all land titles could access water. Most road reserves were originally surveyed at one chain (20.12 m) width to facilitate the transport of horse and carriages - which is barely enough room for modern-day transportation needs.

To mark out the boundaries road reserves, a line of blazed trees were marked 'with a broad arrow at least 6 inches long', where a shield was marked on the tree by stripping off the bark. As road construction was a low priority in the late 1800s, most of the 'roads' formed in these land reserves were no more than a boggy collection of unformed earthen tracks. Depending on usage by transport, major roads were surveyed at much greater widths of up to 2 or 3 chains. In this way, extensive linear tracts of land were retained for transport use, and later cleared of vegetation for roads as neces-

Figure 1. A minor road in a rural area of south-eastern Australia, showing remnant Eucalyptus wood lands located within the road 'reserve'.

sary. The (indirect) legacy of these past land-use decisions is an extensive network of vegetated corridors traversing the country (Spooner 2005) (Figure 2).

Travelling Stock Routes (TSRs) are also an integral component of Australian minor rural road networks. In the 19th century, many stock routes were surveyed up to ½ or 1 mile wide, however most are now 3 chains (60.2 m) in width. It has been suggested that many TSRs originated as trails of indigenous peoples, tracks of native animals, bullock tracks of early explorers or overlanders, or as routes between early settlers homes, water-points and townships. The origins of TSRs are therefore of great historical interest, as they are a lasting imprint of people and transport patterns from long ago (Cameron and Spooner 2010, Spooner et al. 2010). Owing to their width and extent, TSRs are gaining attention for their conservation values, where many still exist as part of the minor rural road network. Similarly, the conservation importance of stock routes is gaining renewed attention elsewhere in countries such as Spain and Britain.

Management of minor rural roads – challenges

In the early 20th century, the road network in Australia amounted to no more than an ad hoc collection of minor rural roads, where travellers navigated their way through vegetated areas on poorly formed tracks. Newly formed local government (council) authorities

Figure 2. A typical road network in south-eastern Australia, showing a major highway tracking through a gridwork of vegetated road reserves, most of which are only 20.1 m wide. This region was previously vegetated with grassy woodlands, which are now mainly confined to roads and other small reserves.

were confronted with the enormous task of making this network trafficable, where road reserves that were actually being used for transport were then declared as 'open' roads. Development of road networks continued throughout much of the early 1900s, where open roads was cleared of vegetation to formally develop roads, and other road reserves eventually closed. These closed road reserves still exist as narrow vegetated corridors, providing enormous opportunities for conservation projects in rural areas (Figure 2).

Since the 1980s, there has been increasing attention toward the conservation management of rural roads and stock routes for their biodiversity and connectivity values (e.g. Bennett 1991, SANVC 1992, Hobbs 1992, Lord 1992). Bodies such as the NSW Roadside Environment Committee (REC) were formed to encourage the better management of the roadside environments, by providing training and assistance to identify the natural and cultural heritage values of roadsides. For example, most council's have now used a rapid bio-assessment methodology of some kind to assess the conservation values of each road segment (ranked as High, Medium or Low). These rankings are then used to determine appropriate management actions for each road category, as described in local roadside management plans (NSW Roadside Environment Committee 2014).

However the management of minor roads is problematic, where legislation requires councils to address a number of competing values, and manage roads accordingly

Table 1. Overview of competing values and management considerations of minor rural roads [1]

Roadside value	Description and management considerations
Connectivity	Prime function of road for humans Wildlife collisions (links to road safety) Dispersal conduit for species
Cultural heritage	Historic bridges, aqueducts, cuttings, Location for scar trees, monuments, memorials, and other built objects of historic significance, Historic road, stock routes, drove roads, driftway, sunken roads.
Ecotourism values	Route to explore sites, localities or landscape Interpretation signage and other infrastructure
Environmental	Refuge for threatened species and ecosystems Seed source for revegetation activities Weed and pest management Fire and timber management Provision of ecosystem services e.g. pollination
Infrastructure corridor	Corridor for water supply, electricity, gas and telecommunications Vegetation clearance for utilities
Recreational	Sight-seeing, horse riding, hiking, bike riding educational values
Resources	Source of firewood/ rocks/ gravel and sand Stock grazing for fodder during drought Stockpiling of materials for road management
Roadside amenity	Aesthetic values of roadside Litter management Transport parking areas
Transport and road safety	Legal requirements/ insurance, Road upgrade, construction and maintenance requirements, Soil stability management/ landslides, Water runoff, run-on control, flooding, snow and ice.

([1]) Adapted from Pauwels and Gulinck 2000, NSW Roadside Environment Committee 2014 and works by the author.

(Table 1). For example, efforts to conserve biodiversity in road reserves must be balanced with road safety and fuel reduction priorities. This is no easy task, where efforts to maintain roadsides vary enormously from one council jurisdiction area to the next. Unfortunately, many rural councils cannot afford a dedicated environment officer, and so compliance to any roadside vegetation conservation plan is often lacking. Roadside vegetation plans need to be promulgated in local by-laws for compliance to take place. A further problem is that roadside environment conservation training for workers is often lacking or non-existent, and local contractors are often over-looked in the training process. Ongoing training and monitoring is critical to ensure that workers know exactly where high quality/ conservation value sections are, so as to avoid damage by heavy roadworks machinery. To this end, simple marking (signage) of roadsides (using colour-coded markers on existing road reflector posts) has been successfully implemented in many council areas to warn road workers of sensitive vegetation areas.

In Australia and elsewhere, it is critical for state and federal environmental agencies to provide necessary resources to local government road managers to conserve roadsides.

Given that conservation outcomes derived from roadsides can greatly contribute to catchment or state based conservation targets, these assets cannot be ignored. Also in terms of future climate change scenarios, a green network is already in place to assist native species to disperse across the landscape. In this context, it is vital that roadside vegetation networks are maintained and even improved with further restoration programs. Ongoing monitoring of roadsides is also vital, as vegetation conditions can both improve and deteriorate, depending on prevailing disturbances (i.e. stock grazing, fire, flood, or soil disturbances from road maintenance activities).

Opportunities for conservation of minor roads – identifying heritage values

The retention of native vegetation along minor roads has many ecological, as well as important economic, aesthetic and social benefits (Breckwoldt 1990). Economic benefits that minor roads provide include a reduction in road management costs associated with conservation priorities, or a rise in ecological-based tourism (Durrant 1994). Social benefits which may occur include the preservation of cultural and natural heritage. Studies have also described important aesthetic benefits for road users travelling along natural landscapes (Cackowski and Nasar 2003). Minor roads also provide service corridors for powerlines, water, sewage, gas, telecommunication and other utilities (Table 1).

An example of one the 'new' values that minor rural roads possess is that of an historic road. As discussed, many minor roads in Australia follow the tracks of early explorers and settlers, some of which may have indigenous origins, and therefore possess important cultural heritage values as an historic road. As such – many have a story to tell, which could be a useful approach in interpreting and educating the general public of associated biodiversity conservation values of minor roads. Roads can have important cultural heritage values for the physical structures they possess (such as old bridges), but also for possessing uncommon, rare or endangered aspects of a regions cultural or natural history (e.g rare or endangered plants or ecosystem). In turn, these species, habitats, and remnant ecosystems provide important aesthetic and social values, which are often unique to a local community.

Formal listing of specific road reserves, or stock routes, on state and national registers may result in opportunities to gain additional funding for management from sources otherwise not considered. However the criteria for listing an historic road are often not well understood. The term immediately evokes thoughts of famous roads such as Route 66 in the USA, or the Great Ocean Road in Victoria, Australia. Depending on the legislation that applies, a road can be listed as an 'historic road' if it is important in the course, or pattern, of the states cultural or natural history, or possesses uncommon, rare or endangered aspects of the states cultural or natural history (*NSW Heritage Act* 1977, Amended 1998). The benefits of identifying, preserving and managing a minor rural road as an historic road are diverse. They may include opportunities for tourism (ecotourism routes, which include historic and natural values) and economic development, and

assistance for restoration of historic structures and features such as bridges, survey trees, indigenous camp sites etc. Such an approach may foster community pride associated with a more comprehensive understanding of a local area's cultural and transportation heritage. Importantly, understanding the development history of roads can provide an important tool to gain new awareness of roadside environmental values, and facilitate greater community investment in their ongoing management (Spooner 2007).

Conclusions

Local councils, NGO environmental organisations, naturalist groups, and other larger state-based and federal agencies face ongoing challenges in managing the competing values of minor rural road networks. In terms of their environmental values, key threats such as invasive species and pollution from adjacent areas require constant vigilance. As human constructions, the key to success in ensuring the persistence of roadside vegetation is in addressing ongoing human impacts. Therefore it is vital that road managers place a greater emphasis on the conservation importance of roadside habitats, and minimise the impacts of disturbances associated with road maintenance and construction activities.

Given the conservation importance of many roadside environments, councils and state managers should "think outside the box" in regards to future road upgrade programs. As described, minor roads often provide refuge for threatened species and ecosystems. Therefore any attempt to upgrade and widen a road will no doubt require expensive mitigation or restoration strategies where conservation values are impacted upon by the development. Alternative strategies need to be explored such as: (1) expanding the road corridor width, by acquiring adjacent farmlands if necessary, to provide opportunities to encourage natural regeneration of native species into surrounding areas, and (2) moving the road – rather than widen the road and impact upon roadside vegetation, it may be feasible to close the road, and build a new carriageway on adjacent cleared farming lands instead. In this way, remnant habitats are left intact.

Linear features such as minor roads are often critical for conserving flora and fauna in rural landscapes, and in providing potential 'conduits' for improving connectivity between fragmented populations (Spooner and Smallbone 2009). The importance of vegetated minor roads will only become more pressing with climate change, where the value in preserving and maintaining vegetated road reserves may be fully realised.

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